High Pressure Core Spray Reliability Study

1 HPCS SYSTEM FAULT TREE

The operational unreliability of the HPCS system was calculated using the simple fault tree model shown in Figure 1 and Figure 2. The model was constructed to reflect the failure modes identified in the unplanned demand and cyclic/quarterly test data. Furthermore, the fault tree model of the HPCS system consists of two sub-trees for the two major HPCS subsystems: injection and emergency power. The following failure modes were developed:

<u>HPCS injection</u>

- Failure to start, other than the injection valve (FTSI)
- Failure to start, injection valve (FTSV)
- Failure to run, other than suction transfer (FTRI)
- Maintenance-out-of-service of the injection subsystem (MOOSI).

For the operational model, the HPCS emergency power was treated as an undeveloped event. The primary reason for using an undeveloped event is that the failure information contained in the unplanned demand data identified only safety injection demands with no concurrent undervoltage condition on the Division III bus. The normal power to the Division III bus was available during all these events. The philosophy for calculating the HPCS operational unreliability is strongly predicated on the unplanned demand data (that is, no need for emergency power). Further, the suction transfer failure mode was left out since the unplanned demands did not identify any challenges of this function. Recovery failure modes with no failure data are also modeled as undeveloped events. The undeveloped events are depicted by a diamond shape in the fault tree.

For the purposes of quantifying the fault tree, the following conditions were assumed:

- A demand to provide core spray to the RPV is received by the HPCS system
- The FTR contribution to the unreliability is estimated on a per mission demand basis
- The normal offsite power is available to the Division III bus
- No suction transfer to the suppression pool is required.

2 HPCS ASSUMPTIONS

The fault tree models shown in Figures 1 and 2 of the fault tree section present the logic for calculating HPCS system unreliability based on postulated conditions.

For the purposes of quantifying the fault tree, the following conditions were assumed:

- A demand to provide core spray to the RPV is received by the HPCS system
- The HPCS system is required to be operable for 24 hours

- The FTR contribution to the unreliability assumes a mission time of 24 hours
- The normal offsite power to the Division III electrical bus is not available
- The HPCS system is assumed to require automatic transfer of suction from the CST to the suppression pool.

To provide consistency in comparisons of PRA/IPE results to corresponding results of analysis of experience, the contributions to the HPCS unreliability from support systems outside the HPCS boundary were excluded from the PRA/IPE models. The recovery event of failure to recover from FTRD is included in the unreliability analysis of the 1987–1993 experience. The recovery failure modes identified in the data are defined such that actual diagnosis (beyond identifying the need to attempt re-starting the system) and repair of HPCS system is not required to make the system operational. Generally, the events listed in these categories require a simple restarting of the system if the automatic initiation circuitry did not start the system. Hence, the estimate of HPCS unreliability includes recovery. PRA/IPEs may model this type of event at the system level.

Other types of recovery modeled in PRA/IPEs involve actual diagnosis and repair of the components that experience a catastrophic failure. These types of recovery are generally modeled at the accident scenario level (that is, accident sequence cutset) since actual diagnosis and repair of the failed equipment is required. Evaluating the potential for recovery of the various system failures identified in the accident sequence cutset allows the optimum recovery strategy to be considered. This type of recovery is significantly different from the recovery failure modes identified in the 1987–1993 experience (that is, no repair required). Only the recovery requiring no repair is used in the HPCS system calculations.

The failure probability estimates associated with the FTRI mode of HPCS operation were not calculated on a per demand basis as was done for the operational mission analysis of the previous section. An hourly failure rate was used instead to quantify the overall probability of failure to run for the injection subsystem. For these calculations, the injection run times stated in the LERs for the unplanned demands were used. The cumulative run time based on the 31 unplanned demands is approximately 50 hours. One hour of running time was assumed for each cyclic and quarterly test for a cumulative test run time of 266 hours (43 run hours from cyclic tests and 223 hours from quarterly tests). The run time assumed for the tests was based on a survey of Idaho National Engineering and Environmental Laboratory (INEEL) personnel (former plant operators, examiners, maintenance personnel, etc.) who have experience in the operation and testing of the HPCS system. Further, the run times based on cyclic and quarterly tests were only used in estimating the FTRI probabilities. Since the run times are short and no failures were observed in the 316 hours of run time, postulating a time dependent failure rate was not possible. The failure rate based on the sparse data was assumed to be constant throughout the entire mission (twenty-four hours). (The constant failure rate assumption was made in all of the IPEs.) Additional data are needed in order to establish a higher confidence in the failure to run estimate. Details of the total run time calculations are presented in Appendix A.

The FTRD estimates were calculated from the pooled data from unplanned demands and cyclic tests even though the two FTRD data sets were statistically flagged as not poolable (P-value = 0.004). The unplanned demands accounted for two failures in 73 hours, while the cyclic tests resulted in no failures in 1,032 hours for the FTRD failure mode. One of the two failures in the unplanned demands data set is a sequential loss of offsite power at Nine Mile Pt. 2 that resulted in the Service Water system being isolated, thereby causing the HPCS EDG failure to run. Nine Mile Pt. 2 is one of only two HPCS plants that do not have a cooling water system dedicated to the HPCS diesel. In addition, the design of the Service Water was subsequently modified to account for the effect of a sequential loss of offsite power on Service Water system availability. The inclusion of this failure, even though it is unique and was subsequently designed out, resulted in the non-poolable data sets. However, the failure was included for completeness of the failure data and because the failure did affect HPCS system reliability.

In addition to the overall HPCS system unreliability comparisons, the component failure probabilities from the PRA/IPEs were grouped into the same system failure modes defined for analysis of the 1987–1993 experience. The component failure modes identified in the PRA/IPEs were grouped according to the following breakdown:

<u>HPCS Injection</u>

FTSI—HPCS pump failure to start, failure of the actuation circuit, valve failures (except for the injection valve and the valves in the suction transfer paths).

FTSV—Failure of the injection valve to open.

FTRT—Failure of the condensate storage tank suction MOV and check valve, suppression pool suction MOV and check valve, and associated level/actuation circuitry to realign suction sources from condensate storage tank to the suppression pool.

FTRI—HPCS pump failure to run and the failure of the associated room cooler/fan.

MOOSI—HPCS injection maintenance unavailability.

<u>HPCS Emergency Power</u>

FTSD—Failure to start of the emergency diesel generator and associated actuation circuitry.

FTSB—Failure of the Division III EDG output breaker to close.

FTRD—Failure of the Division III EDG to run and the HPCS dedicated service water cooling pump failure to start and run (River Bend and Nine Mile Pt. 2 service water failures were not included since they have no dedicated independent cooling water subsystem for HPCS).

MOOSD—HPCS emergency power (Division III) and dedicated service water cooling subsystem maintenance unavailability.

The majority of the PRA/IPEs stated that the failure of the minimum flow control valve to close would not affect rated flow to the reactor vessel either because of its small size and/or installed flow limiting orifices. Therefore, for these plants, the minimum flow valve failing to close was not included in the unreliability estimate.

While there are additional component failure modes in a given PRA/IPE for the HPCS system, the effect of not including these additional components in the system failure probability estimate is small.

River Bend and Nine Mile Pt. 2 have no independent HPCS dedicated service water system. The service water for cooling HPCS components at these plants is supplied by the main plant service water system. The HPCS unreliability estimates calculated from the PRA/IPEs do not include the contributions from the main service water system for River Bend and Nine Mile Pt. 2.

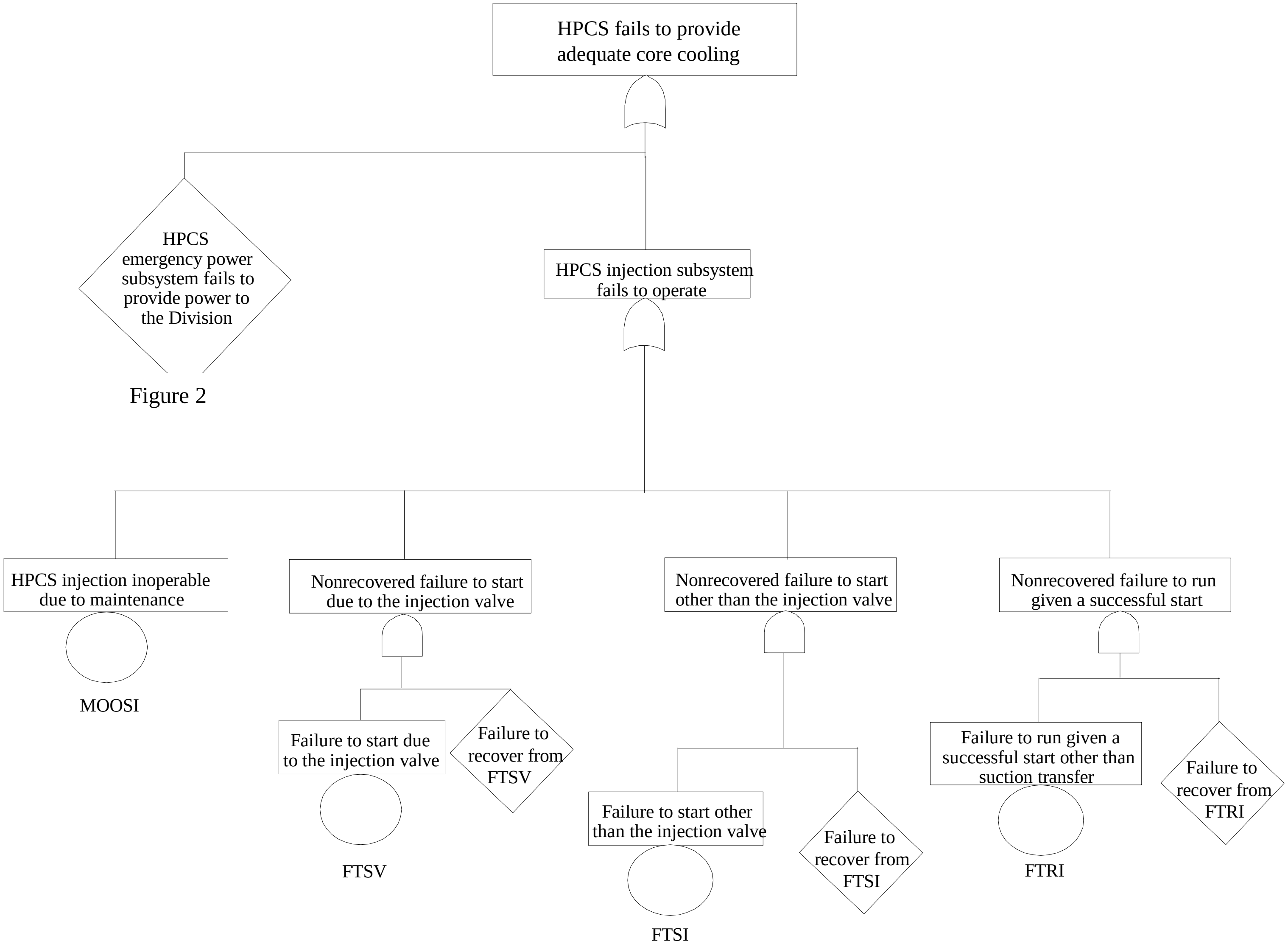

Figure 1. System fault tree of HPCS for calculating operational unreliability.

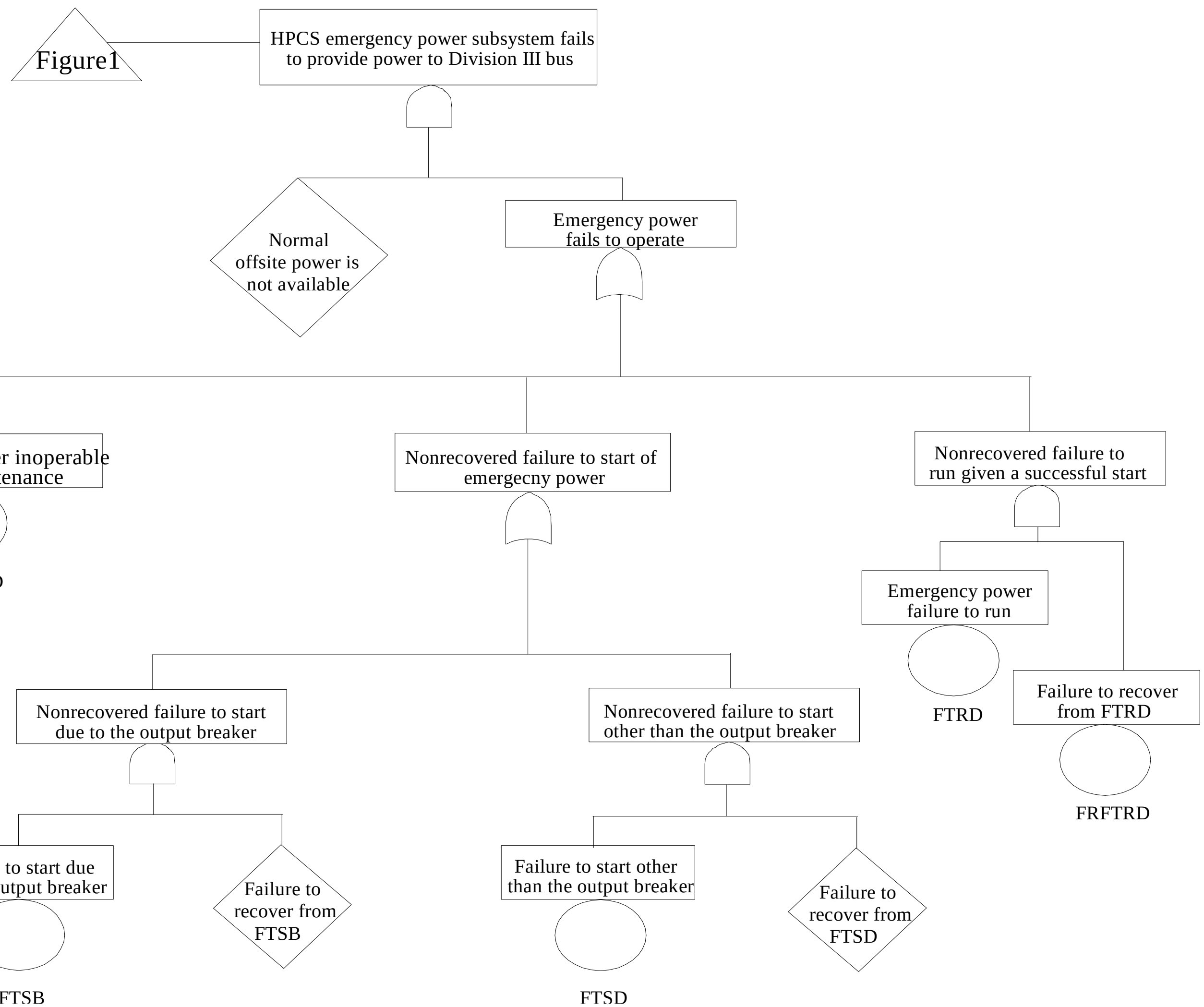

Figure 2. System fault tree of HPCS emergency power.